crystals

MDPI

Editorial

Synthesis and Characterization of Ferroelectrics

Jan Dec

Institute of Materials Science, University of Silesia, Bankowa Str. 12, 40-007 Katowice, Poland; jan.dec@us.edu.pl

Received: 16 September 2020; Accepted: 16 September 2020; Published: 17 September 2020

Ferroelectrics belong to one of the most studied groups of materials in terms of research and applications. Apart from their foremost property (the ferroelectricity), these materials also display other numerous attractive properties such as piezoelectricity, pyroelectricity, electrocaloric and electro-optic effects, etc., which designate them as multifunctional materials. Therefore, these materials are suitable for a wide range of applications ranging from effective sensors, transducers and actuators to optical and memory devices. Since the discovery of ferroelectricity in Rochelle salt in 1920 by Valasek [1], numerous applications using such effects have been developed. In addition, ferroelectrics, and other ferroics, exhibit a highly non-linear response, which is changeable rather than fixed, mimicking, to a large extent, biological systems [2]. Consequently, this kind of behavior is qualified as "smart" and respective systems are termed as "smart materials" [2]. This Special Issue on "Synthesis and Characterization of Ferroelectrics" covers a broad range of physical properties of ferroelectrics, their technological aspects and contains a mixture of review article and original contributions.

We start with the review paper by Liu et al. [3], which summarizes the recent progress on lead-free (BaCa)(ZrTi)O_3 (BCT-BZT for short) piezoelectric ceramics. Different substitution mechanisms offer some thoughts towards the future improvement of BCT-BZT ceramics including the electrocaloric effect, fluorescence and energy storage. Element segregation along axial and radial directions and electrical properties of a relaxor-based single crystal with nominal composition of 0.68Pb($Mg_{1/3}Nb_{2/3}$)-0.32$PbTiO_3$ (PMN-32PT) were investigated by Wang et al. [4]. It is found that such segregation differently influences the electrical properties of the investigated system. While the electrical properties along the axial direction strongly depend on the $PbTiO_3$ content, the electrical properties along the radial direction are mainly determined by the ratio of Nb and Mg. Another technological route is presented by Li et al. [5]. The authors investigated dielectric and conductivity mechanisms of Fe-substituted PMN-32PT crystals. This heterovalent ionic substitution led to enhancement of the coercive field due to wall-pinning induced by charged defect dipoles. On the other hand, the dominating conduction carriers are electrons arising from the first ionization of oxygen vacancies.

Two papers are dedicated to thin-film capacitor applications. The results on structure and electrical properties of lead-free $Na_{0.5}Bi_{0.5}TiO_3$ based epitaxial films are reported by Song et al. [6]. Pt/$Na_{0.5}Bi_{0.5}TiO_3$/$La_{0.5}Sr_{0.5}CoO_3$ (Pt/NBT/LSCO) was fabricated on a (110) $SrTiO_3$ substrate. Both NBT and LSCO films displayed (110) epitaxial growth. The PT/NBT/LSCO capacitor possesses good fatigue resistance and retention, as well as ferroelectric properties. Another lead-free thin-film capacitor is based on $Ba_{0.3}Sr_{0.7}Zr_{0.18}Ti_{0.82}O_3$ (BSZT) compound [7]. The obtained BSZT films feature a low leakage current density of the order of 7.65×10^{-7} A/cm^2, and breakdown strength as high as 4 MV/cm. In addition, these films exhibit an almost linear and acceptable temperature change of capacitance ($\Delta C/C \approx 13.6\%$) and also large capacitance density of the order of 1.7 nF/mm^2 at 100 kHz.

Finally, the Special Issue ends with a report on an enhanced electrocaloric effect, as observed by Lu et al. [8], in 0.73Pb($Mg_{1/3}Nb_{2/3}$)O_3-0.27 $PbTiO_3$ single crystals. The authors claim that a directly measured change in temperature ΔT >2.5 K of the sample may be observed under an external electrical field which was reversed at room temperature from 1 MV/m to −1MV/m. The reported temperature change is larger than that deduced according to the Maxwell relation and larger than that calculated using the Landau–Ginsburg–Devonshire phenomenological theory. We hope that this contribution will stimulate further research for effective solid-state refrigeration materials as well as refreshing discussion concerned with the investigation methodology of the electrocaloric effect.

The present Special Issue on "Synthesis and Characterization of Ferroelectrics" can be considered as a status report reviewing some progress that has been achieved over the past few years in selected topic areas related to ferroelectric materials.

References

1. Valasek, J. Piezoelectric and Allied Phenomena in Rochelle Salt. *Phys. Rev.* **1920**, *15*, 537.
2. Wadhavan, V.K.; Pandit, P.; Gupta, S.M. PMN-PT Based Relaxor Ferroelectrics as Very Smart Materials. *Materials Sci. Eng. B* **2005**, *120*, 199. [CrossRef]
3. Liu, W.; Cheng, L.; Li, S. Prospective of (BaCa)(ZrTi)O_3 Lead-free Piezoelectric Ceramics. *Crystals* **2019**, *9*, 179. [CrossRef]
4. Wang, S.; Xi, Z.; Fang, P.; Li, X.; Long, W.; He, A. Element Segregation and Electrical Properties of PMN-32PT Grown Using Bridgman Method. *Crystals* **2019**, *9*, 98. [CrossRef]
5. Li, X.; Fan, X.; Xi, Z.; Liu, P.; Long, W.; Fang, P.; Guo, F.; Nan, R. Dielectric Relaxor and Conductivity Mechanis, in Fe-Substituted PMN-32PT Ferroelectric Crystal. *Crystals* **2019**, *9*, 241. [CrossRef]
6. Song, J.; Gao, J.; Zhang, S.; Luo, L.; Dai, X.; Zhao, L.; Liu, B. Structure and Electrical Properties of $Na_{0.5}Bi_{0.5}TiO_3$ Epitaxial Films with (110) Orientation. *Crystals* **2019**, *9*, 558. [CrossRef]
7. Chen, X.; Mo, T.; Huang, B.; Liu, Y.; Yu, P. Capacitance Properties in $Ba_{0.3}Sr_{0.7}Zr_{0.18}Ti_{0.82}O_3$ Thin Films on Silicon Substrate for Thin Film Capacitor Applications. *Crystals* **2020**, *10*, 318. [CrossRef]
8. Lu, B.; Jian, X.; Lin, X.; Yao, Y.; Tao, T.; Liang, B.; Luo, H.; Lu, S.-G. Enhanced Electrocaloric Effect in 0.73Pb($Mg_{1/3}Nb_{2/3}$)O_3-0.27 $PbTiO_3$ Single Crystals via Direct Measurements. *Crystals* **2020**, *10*, 451. [CrossRef]